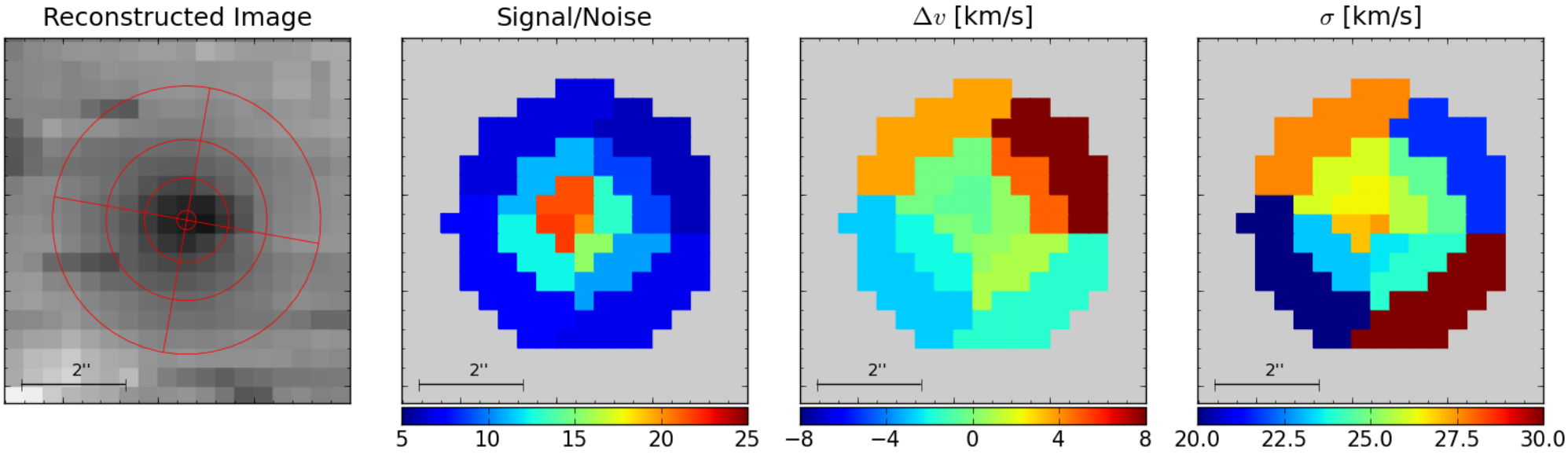
Black holes in ultra-compact dwarf galaxies?

Michael Hilker (ESO/Garching)



No answer in this talk!

Main collaborators: M. Frank, S. Mieske, I. Misgeld (ESO), H. Baumgardt (U. of Queensland); A. Jordan, L. Infante (PUC/Chile)

Characteristics of „Ultra-Compact Dwarf galaxies“ (UCDs)

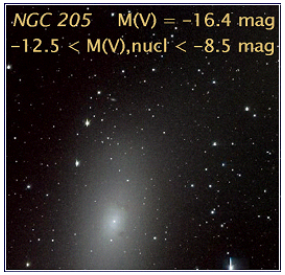
Ultra-compact dwarf galaxies

Luminosities:	**$-13.5<M_V<-11.0$**	(although ω Centauri (M_V=-10.4) might be a small UCD)
Half-light radii:	**$5<R_{h,p}<30$ pc**	(a few have LSB envelopes with $80<R_{eff}<120$ pc)
Velocity dispersion:	**$25<\sigma_0<45$ km/s**	(extrapolated from the observed velocity dispersion)
Mass range:	**$\geq 2 \times 10^6$-10^8 $M_\odot$**	(dynamical mass)
M/L_{dyn}:	**2-10**	(different from the expected M/L of canonical stellar populations)
Occurence:	**In cores of galaxy clusters or close to major galaxies**	

The top 4 formation scenarios for UCDs

"Threshing scenario (remnant nuclei)"

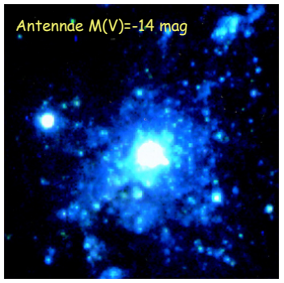
(Bekki et al. 2001, 2003, Bassino et al. 1994, Zinnecker et al. 1988)



vs.

"Massive supercluster complexes"

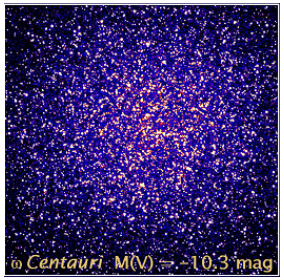
(Fellhauer & Kroupa 2002, 2005, Kroupa 1998)



vs.

"Bright end of the normal GC luminosity function"

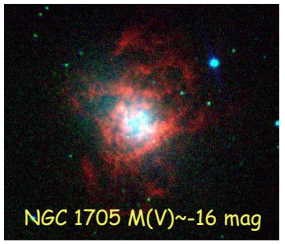
(Mieske et al. 2002, 2004)



vs.

"Genuine compact dwarf galaxies"

(Phillipps et al. 2001, Drinkwater et al. 2004, Richtler et al. 2005)



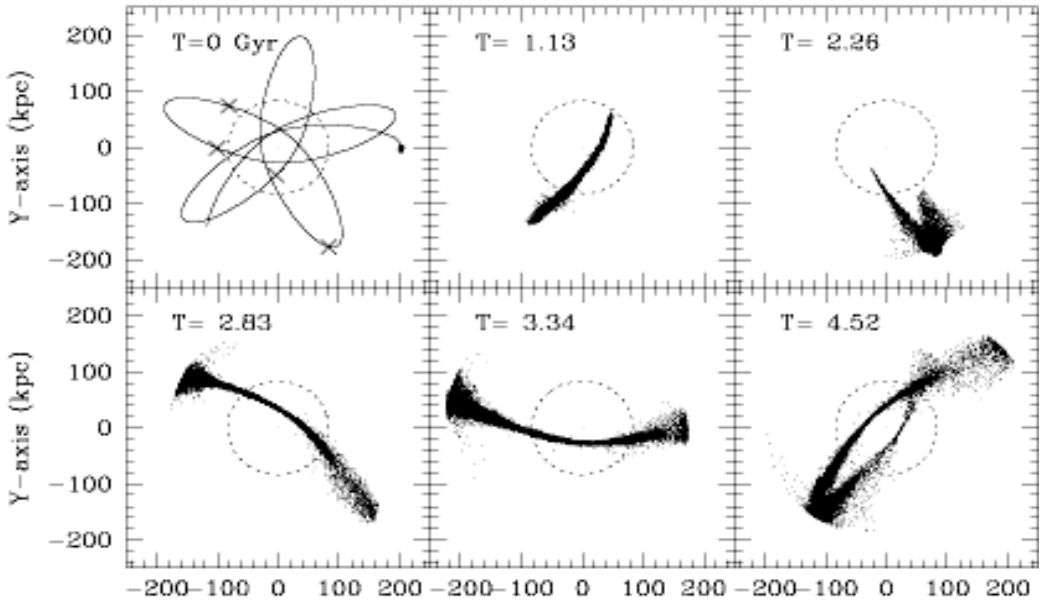
A scenario in which a nuclear star cluster gets isolated by the tidal disruption of its parent galaxy in a galactic/cluster potential was proposed quite some time ago …

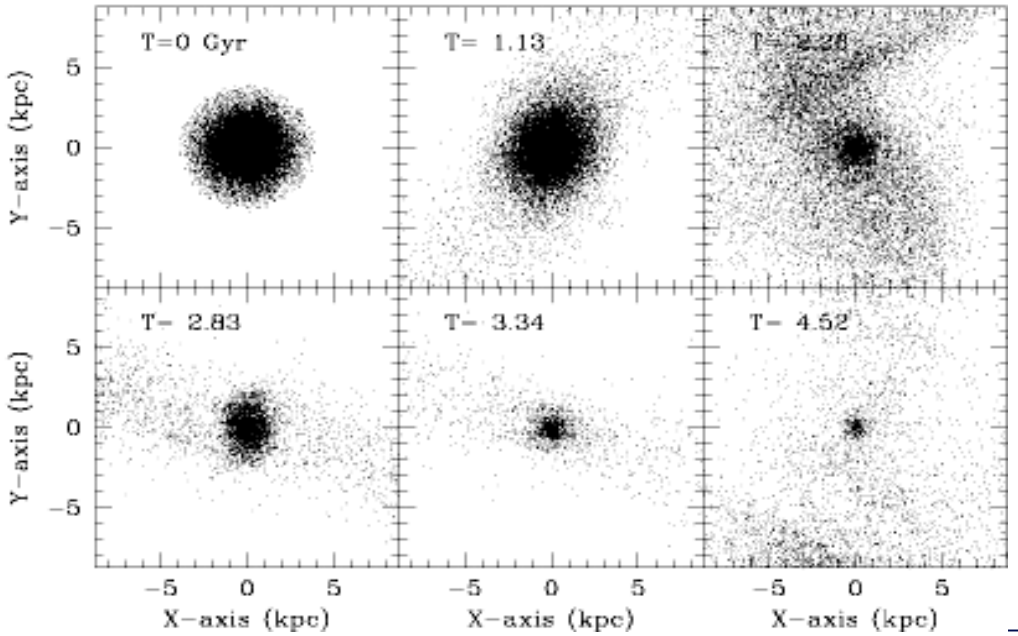
- … for the origin of ω Centauri:
  Zinnecker et al. (1988), Freeman (1993), Lee et al. (1999), Hilker & Richtler (2000), Bekki & Freeman (2003), …
- … for intra-cluster GCs in galaxy clusters:
  Bassino et al. (1994), Hilker, Infante & Richtler (1999), …
- … as a formation channel for UCDs:
  Hilker et al. (1999), Drinkwater et al. (2000), Bekki et al. (2001), …

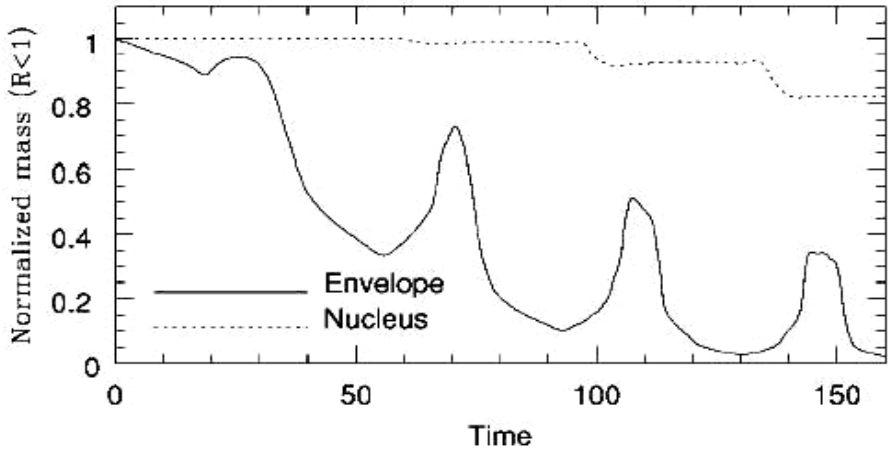
Simulation of UCD formation from the disruption of dwarf galaxies

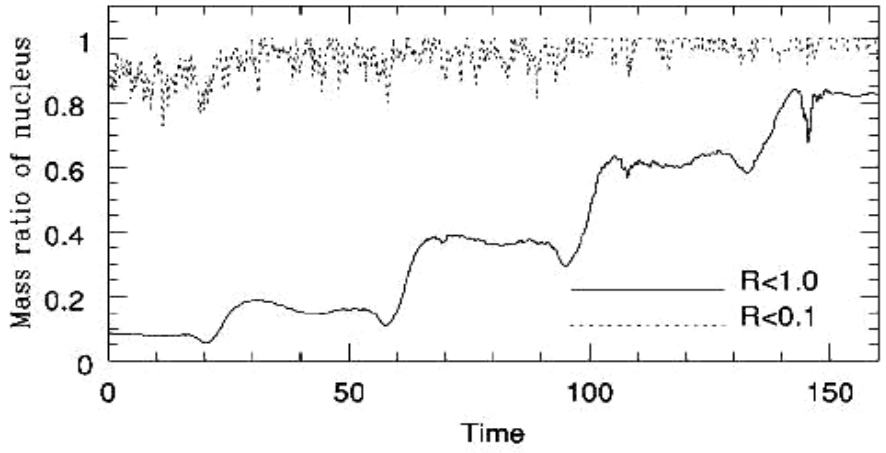
orbit

nucleus mass and mass loss



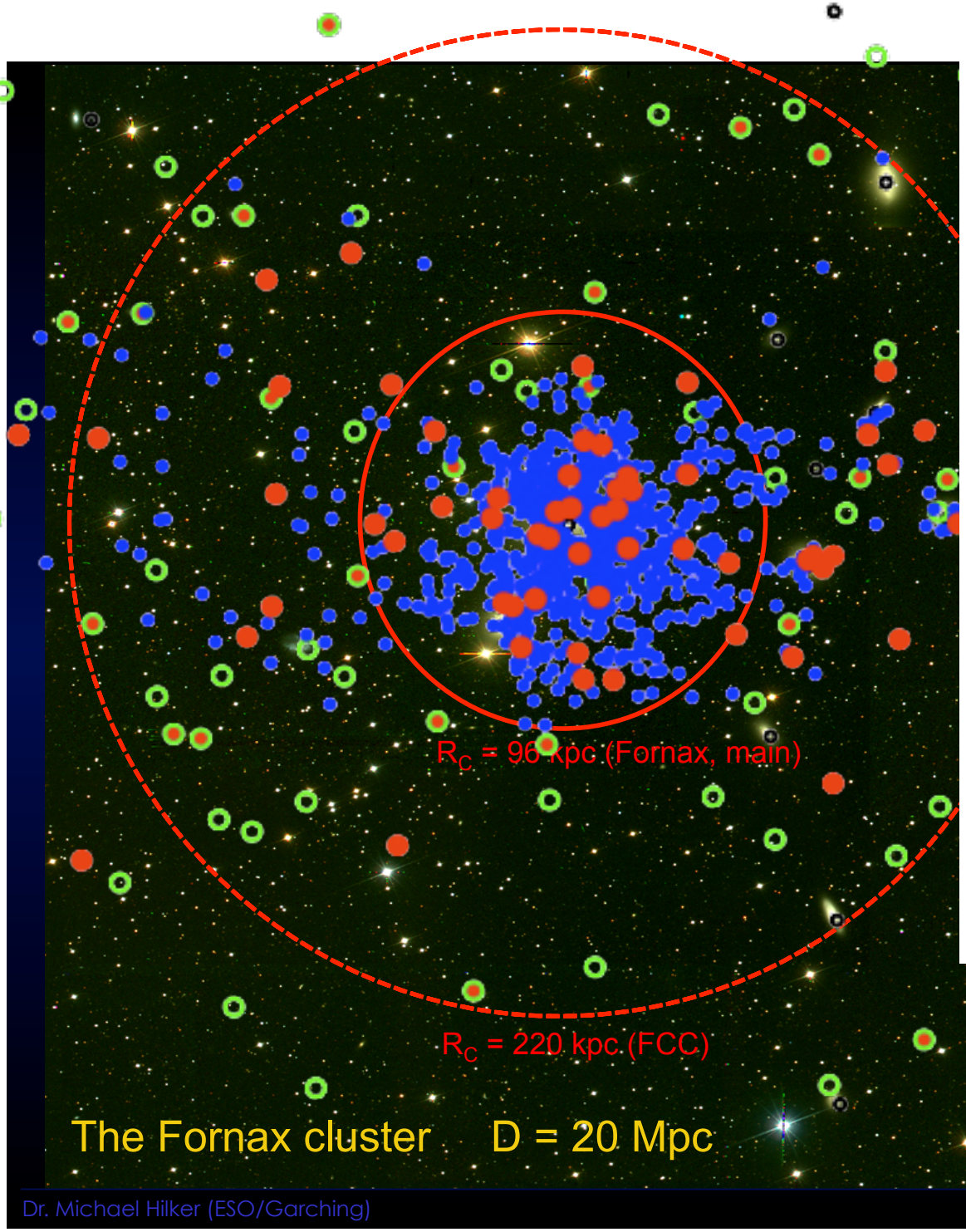


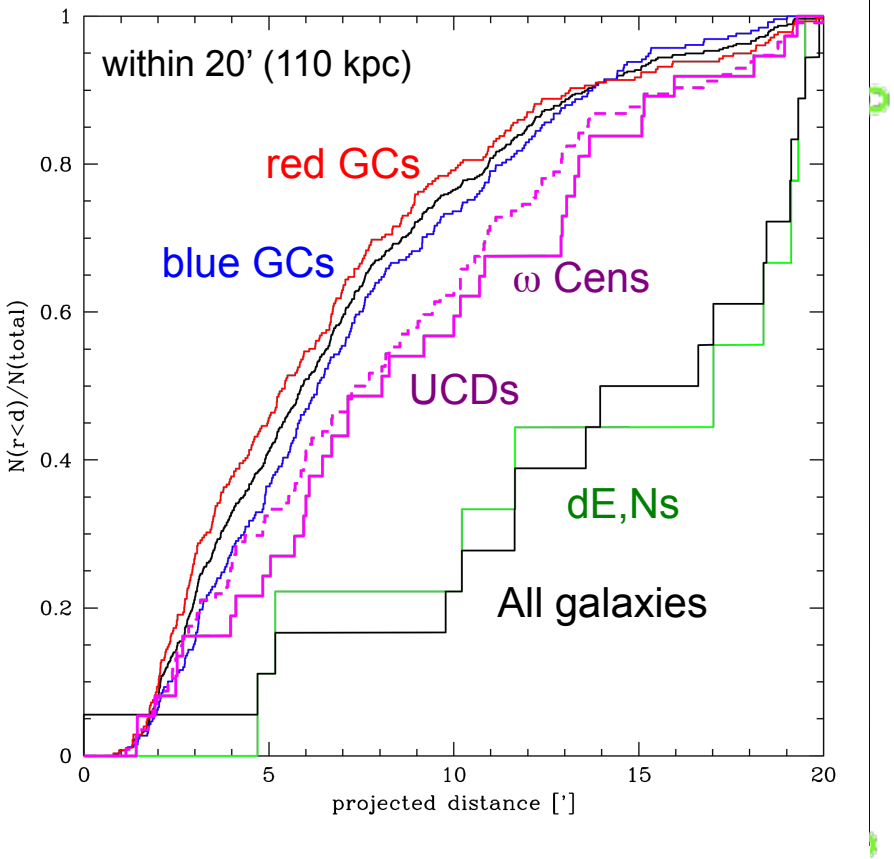




Bekki et al. 2001 (ApJ 552, L105), 2003 (MNRAS 344, 399)

Goerdt et al. 2008: can explain remaining DM in UCDs





red GCs < blue GCs < ωCens < UCDs < dE,Ns < dEs < all galaxies

To be explained:

- **Where are the transition types?**
  UCDs with different envelope sizes are expected.
  Does it mean that the threshing process terminated long ago?

- Present day spatial distributions of dE,Ns and UCDs are quite different from each other.
  Does this point to a selective process, disrupting only dE,Ns that were more centrally concentrated?

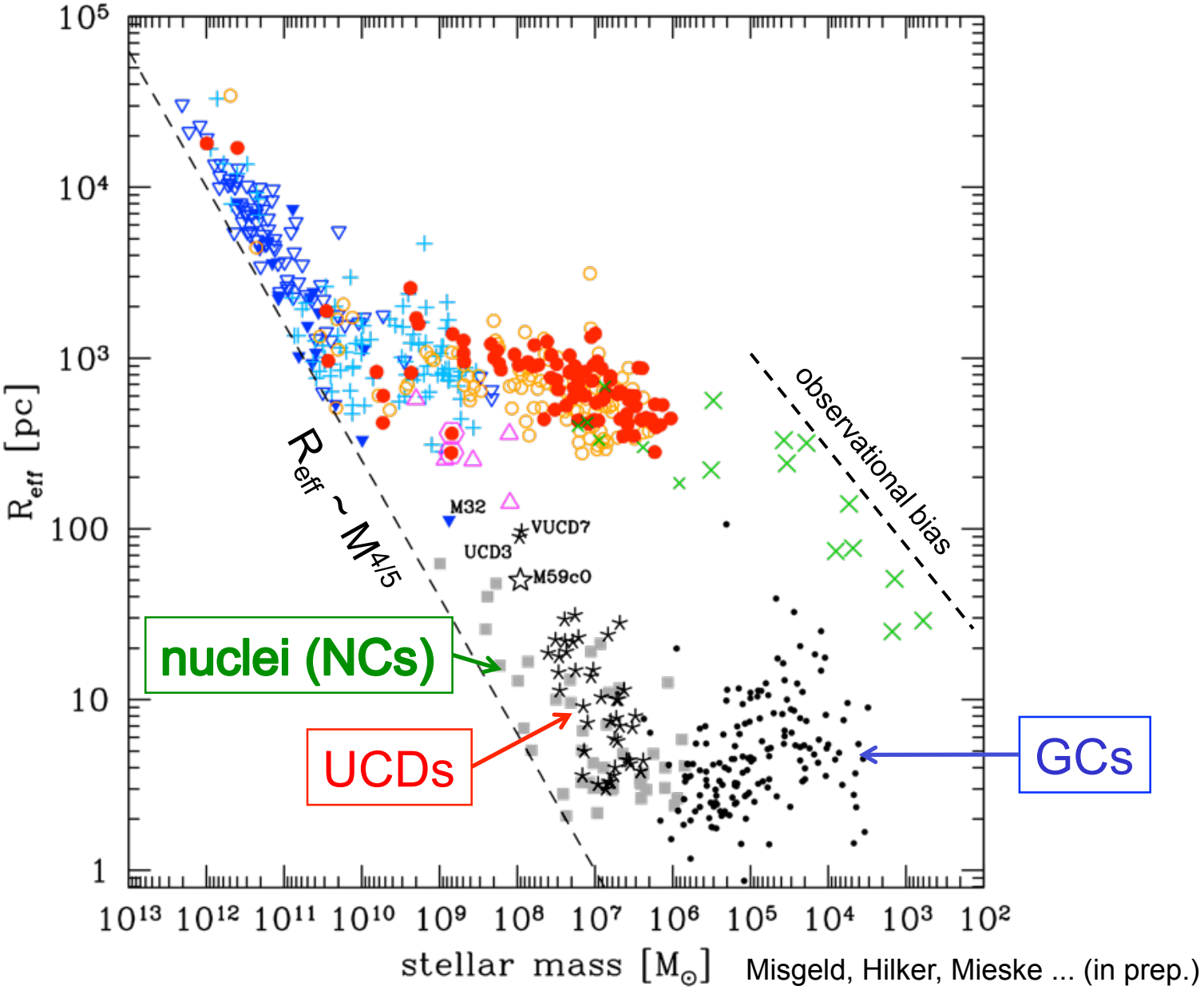
Needed:

- Self-consistent model of galaxy threshing in a CDM framework explaining the sizes and spatial and dynamical distribution of the present-day UCD population

Similarities between UCDs and nuclear star clusters

Mass-size relation of UCDs

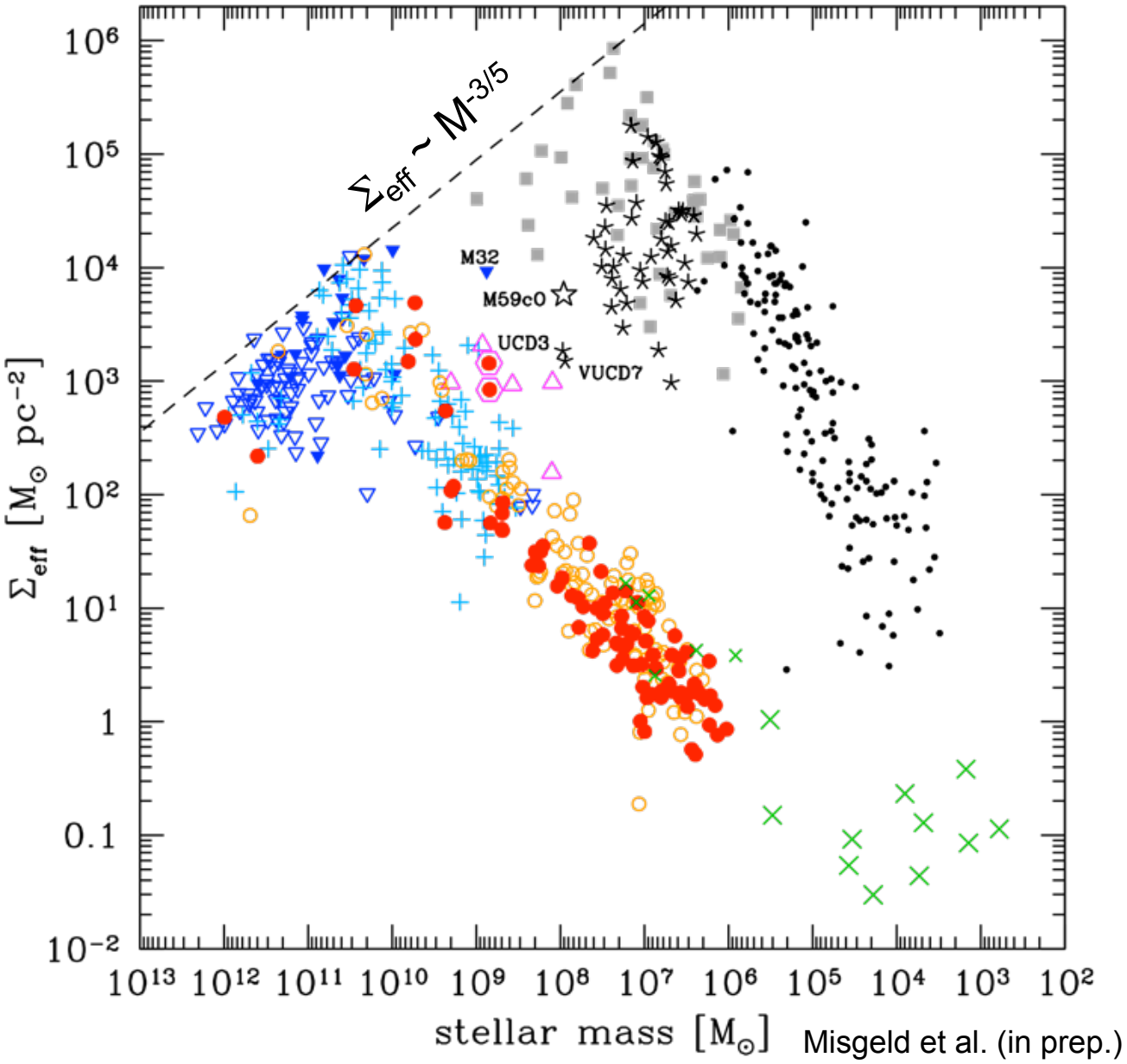
UCDs and NCs are found in the same region of the mass-size space and follow a similar slope in their mass-size relation, but at the same mass, NCs are more compact than UCDs.



Misgeld, Hilker, Mieske ... (in prep.)

Mass-surface density relations

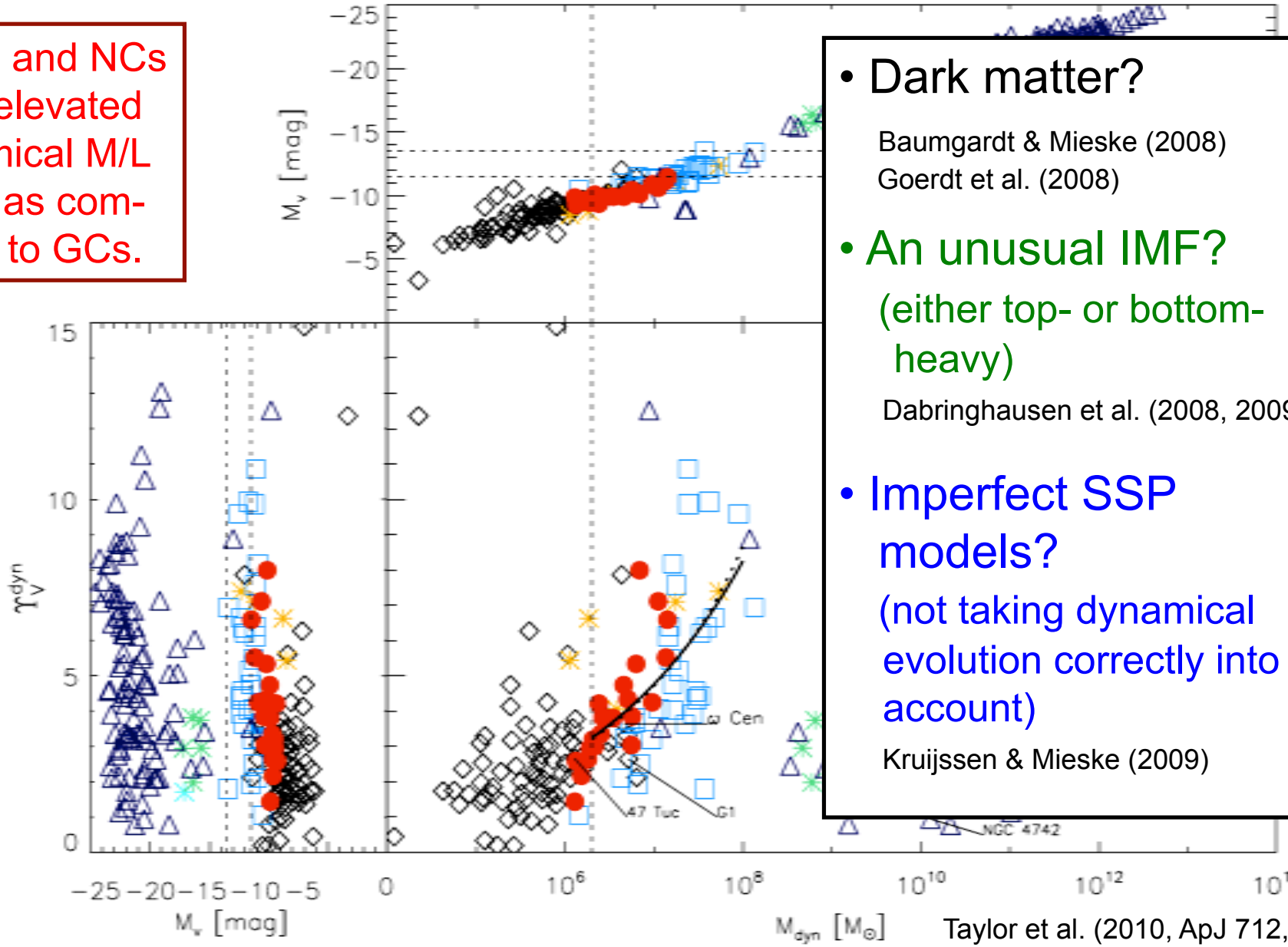
UCDs and NCs belong to the same`star cluster‘ sequence in the mass-surface density space, well separated from the `galaxy‘ sequence.
NCs reach the highest effective surface densities of any stellar system.



Misgeld et al. (in prep.)

Dynamical mass-to-light ratio vs. mass/luminosity

UCDs and NCs have elevated dynamical M/L ratios as compared to GCs.



- Dark matter?

  Baumgardt & Mieske (2008)
  Goerdt et al. (2008)

- An unusual IMF?

  (either top- or bottom-heavy)

  Dabringhausen et al. (2008, 2009)

- Imperfect SSP models?

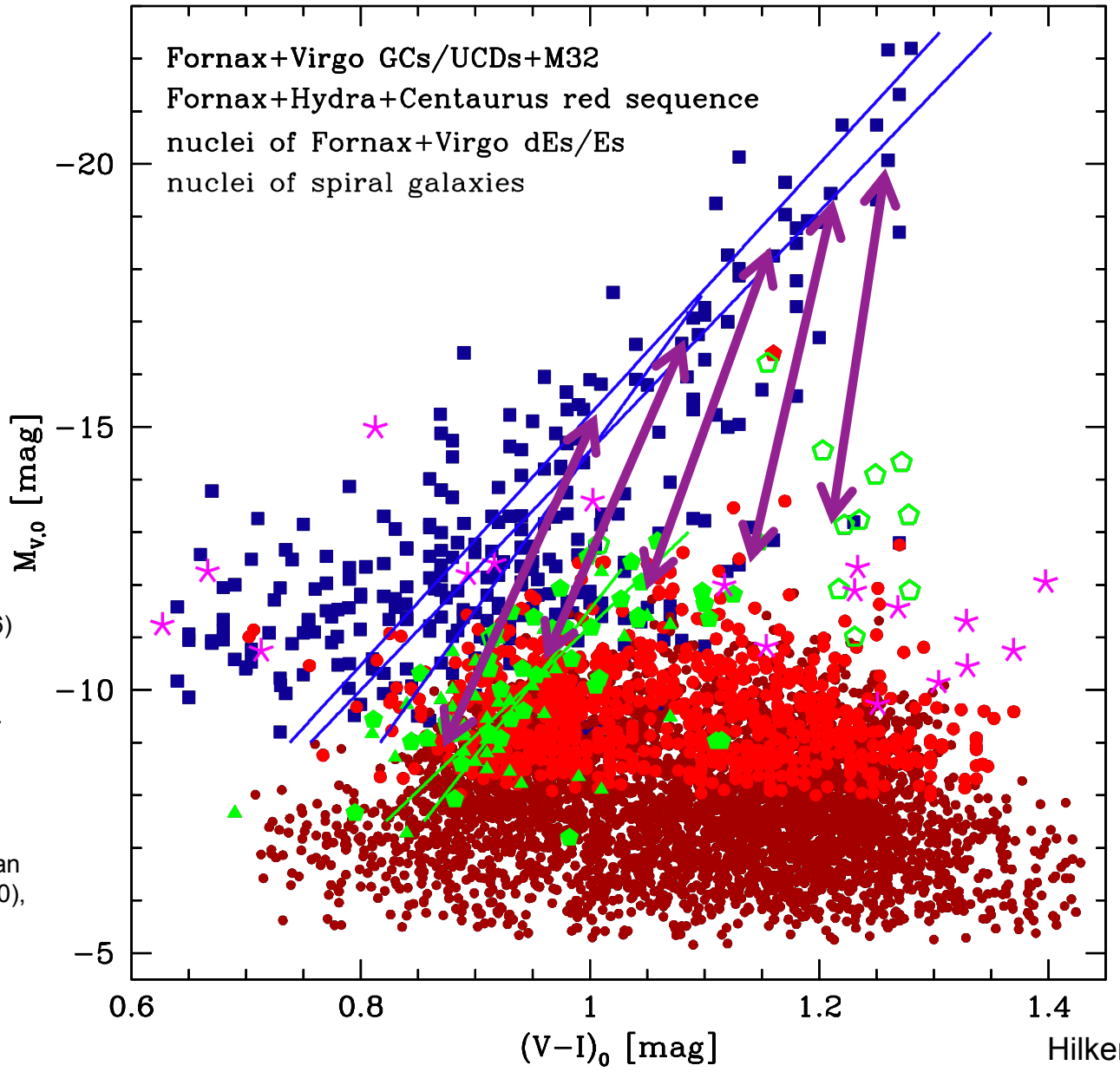
  (not taking dynamical evolution correctly into account)

  Kruijssen & Mieske (2009)

Taylor et al. (2010, ApJ 712, 1191)

CMD for massive GCs, UCDs, early-type galaxies and their nuclei

Similarities to GCs ...
... and to nuclei



Hilker et al. (in prep.)

Galaxies:
Hilker et al. (2003). Mieske et al. (2007), Misgeld et al. (2008, 2009)

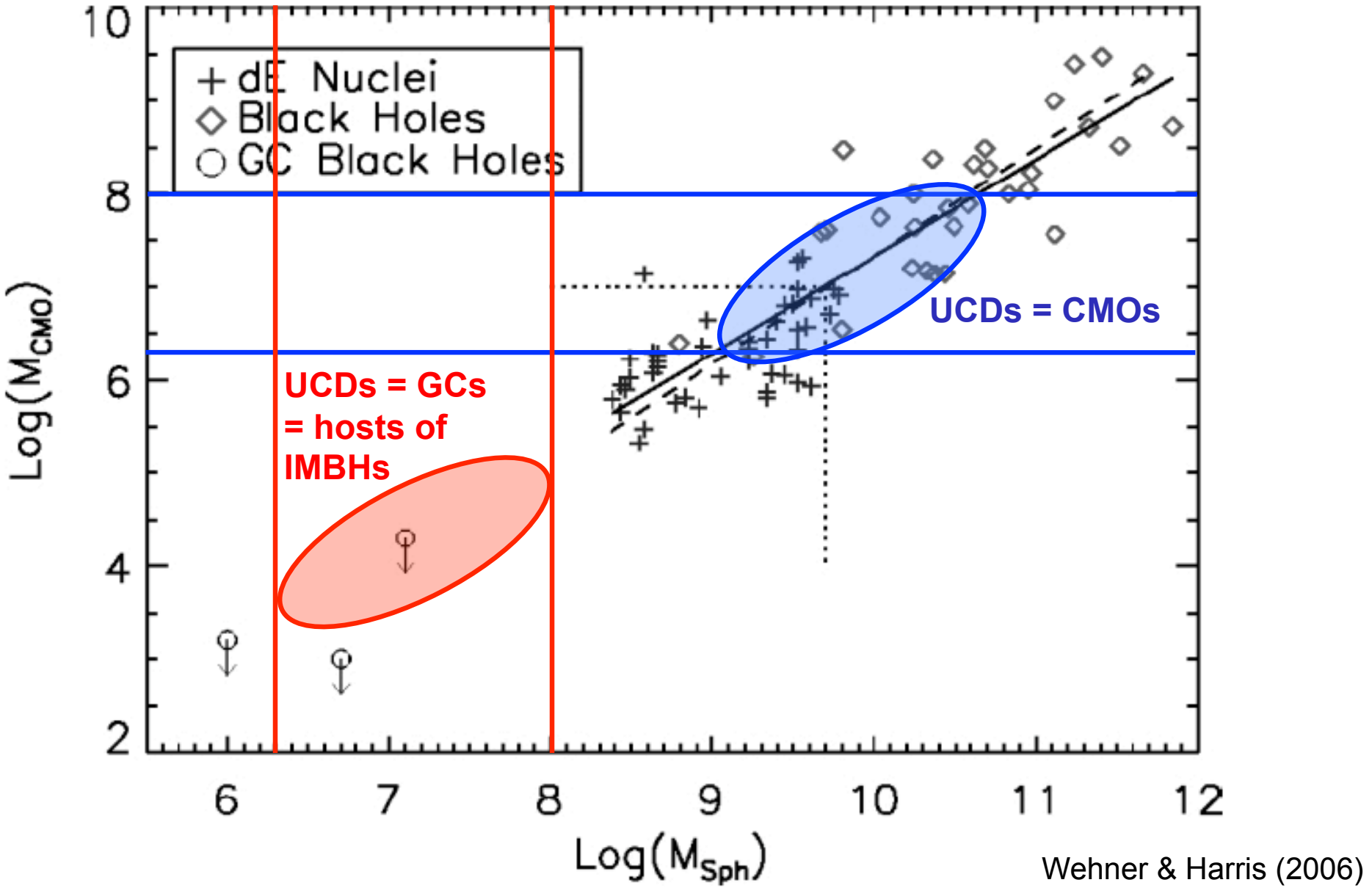
Nuclei of early-type galaxies:
Lotz et al. (2004), Cote et al. (2006)

Nuclei of late-type galaxies:
Walcher et al. (2006), Boeker et al. (2002, 2004), Rossa et al. (2006)

UCDs/GCs:
Drinkwater et al. (2000, 2003), Mieske et al. (2004, 2008), Hasegan et al. (2005), Schuberth et al. (2010), ... and many more ...

GCs (ACS photometry):
Jordan et al. (2009), Peng et al. (2006)

Black holes in UCDs?
What can be expected?

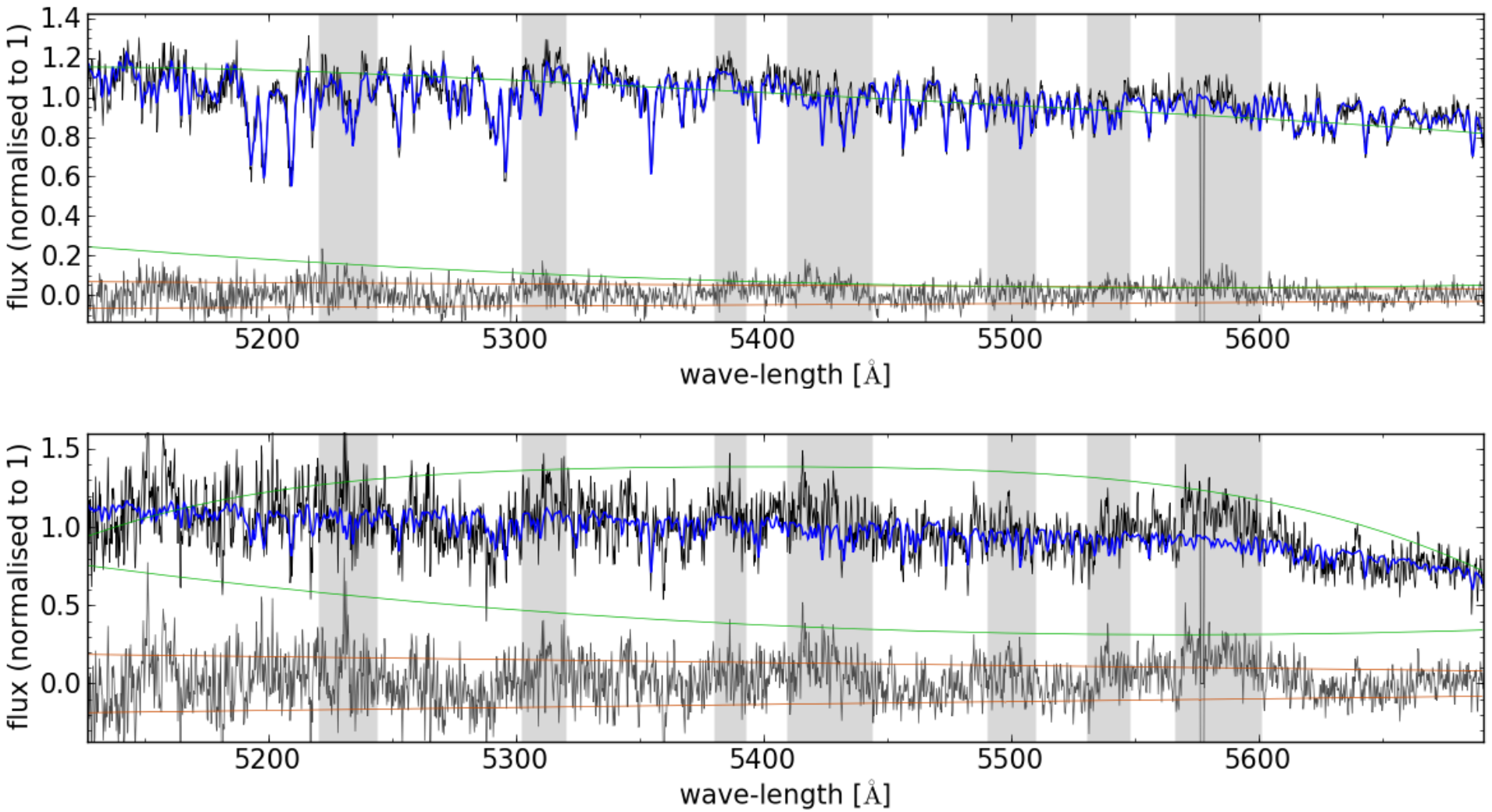


Wehner & Harris (2006)

Resolved internal kinematics of the most massive UCD In Fornax

Dr. Michael Hilker (ESO/Garching)

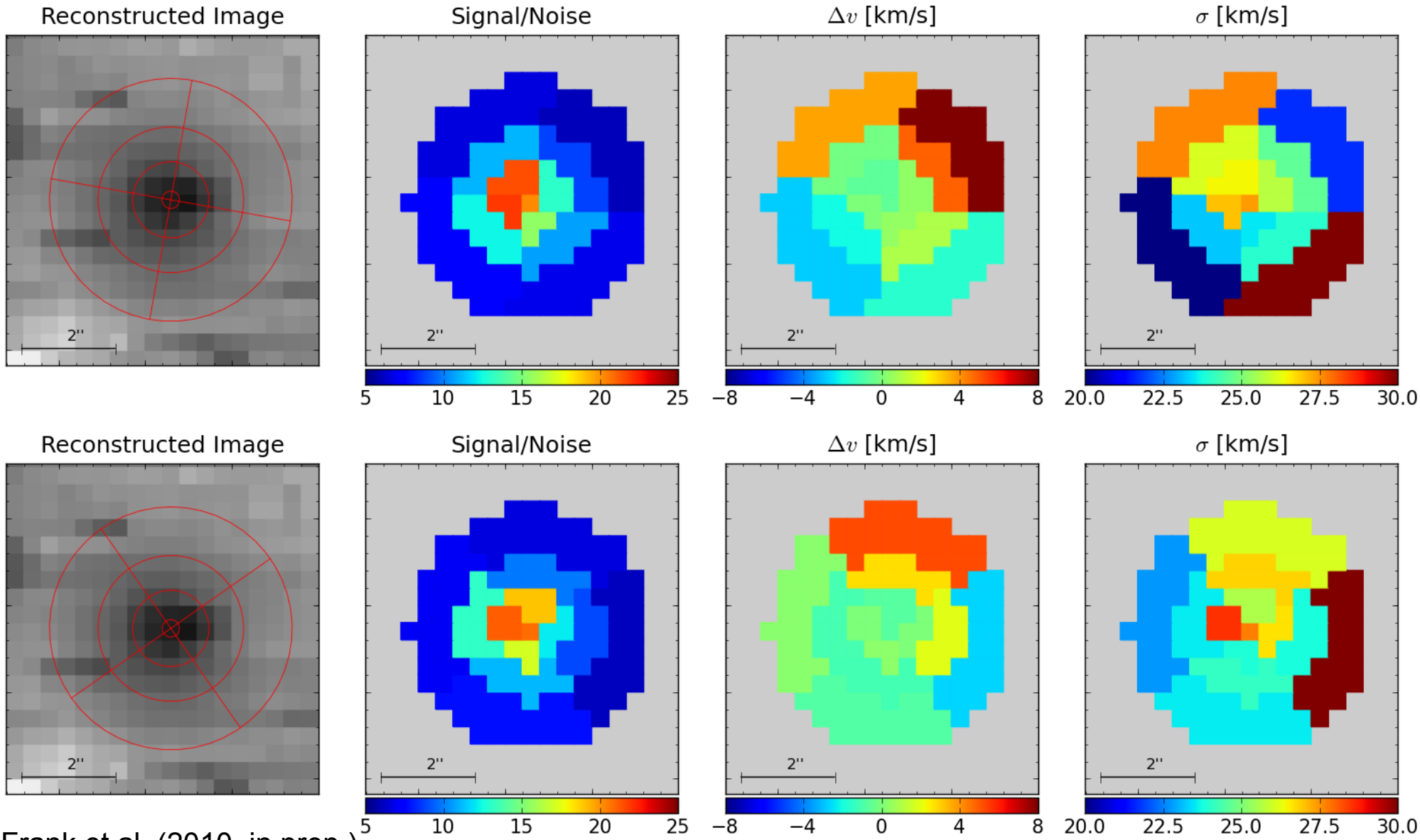
FLAMES/ARGUS IFU spectra of UCD3 in Fornax



analysed with the penalized pixel-fitting method from Cappellari & Emsellem (2004)

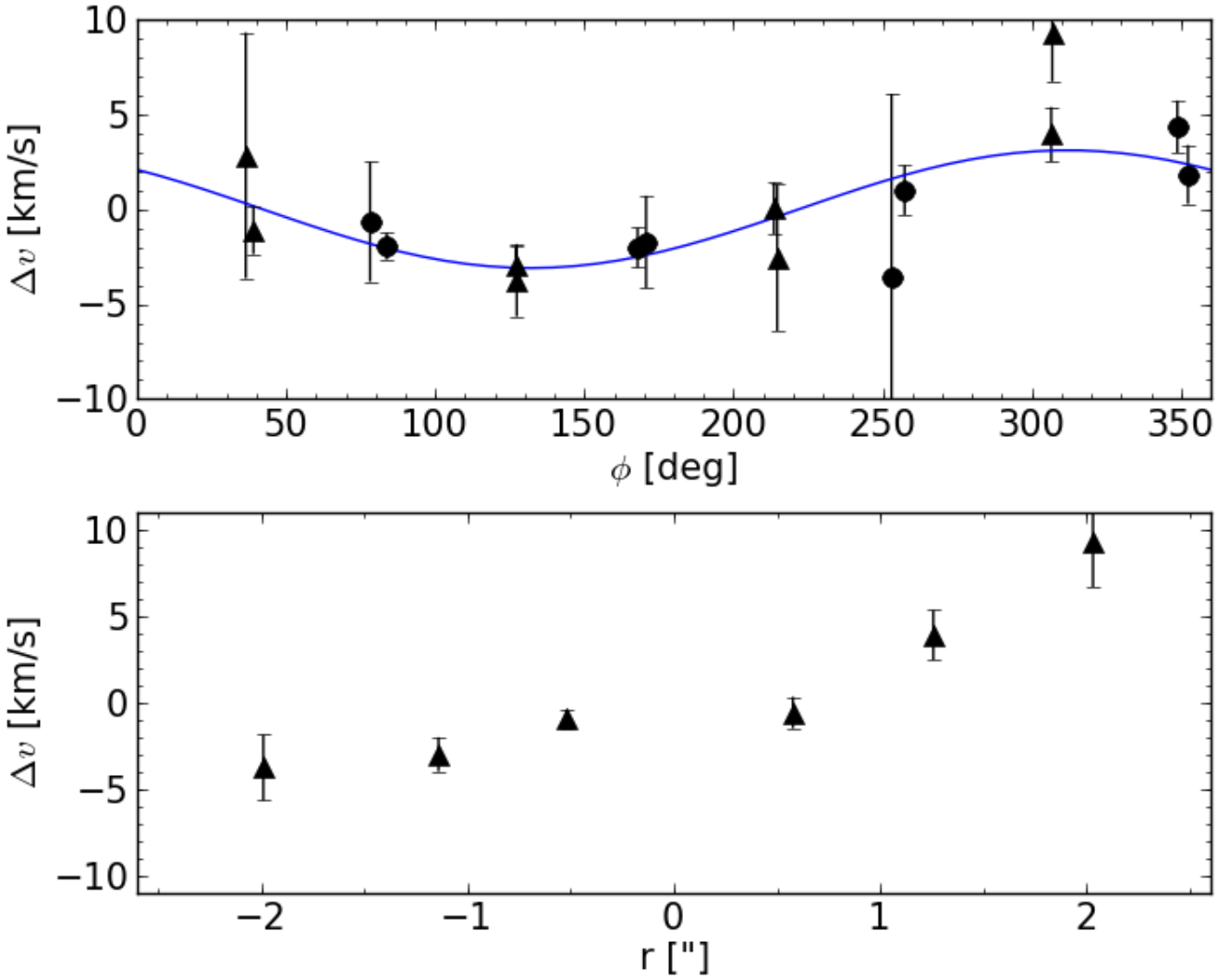
Frank et al. (2010, in prep.)

Different realisations of spatial binning and the resulting maps



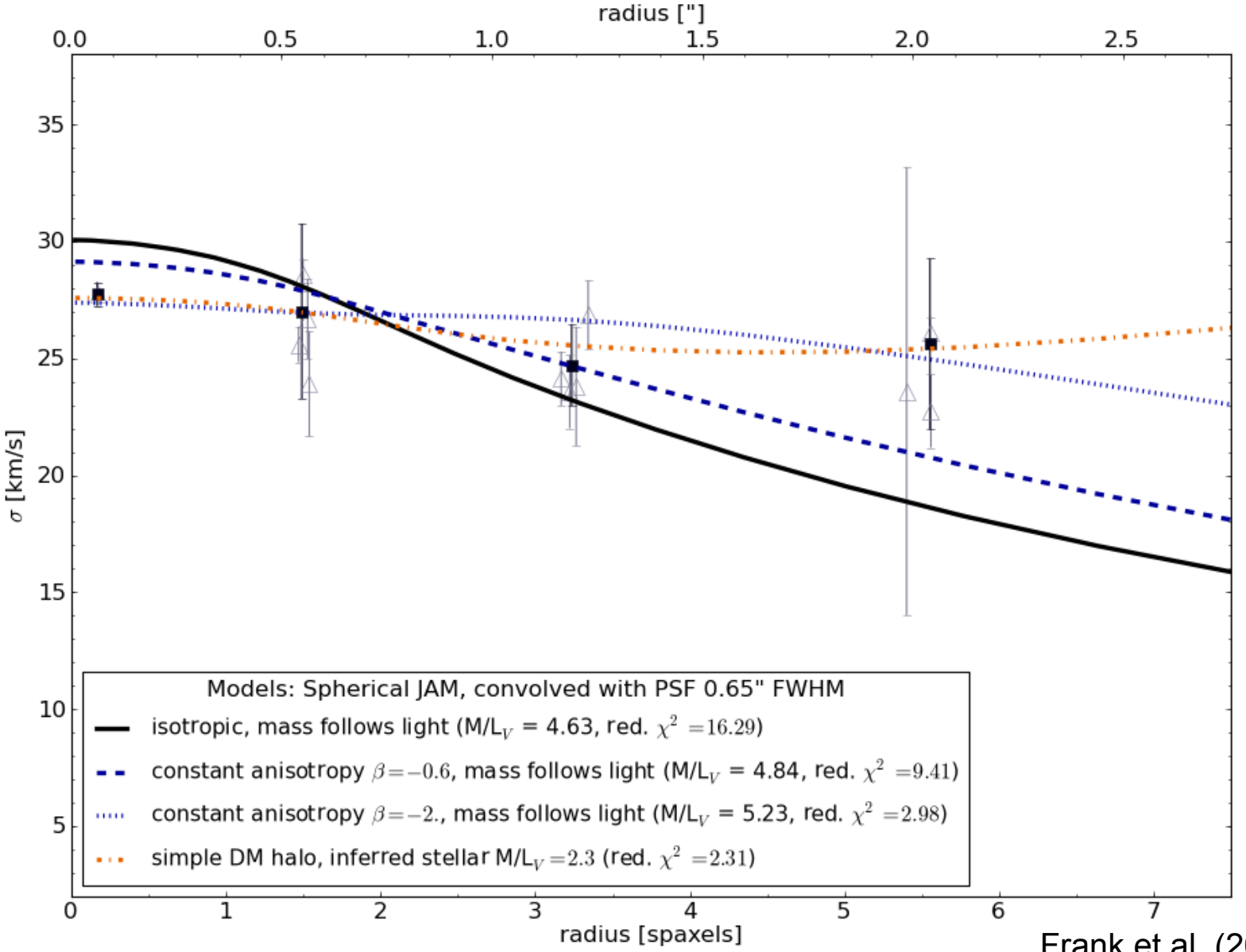
Frank et al. (2010, in prep.)

Signature of rotation in UCD3



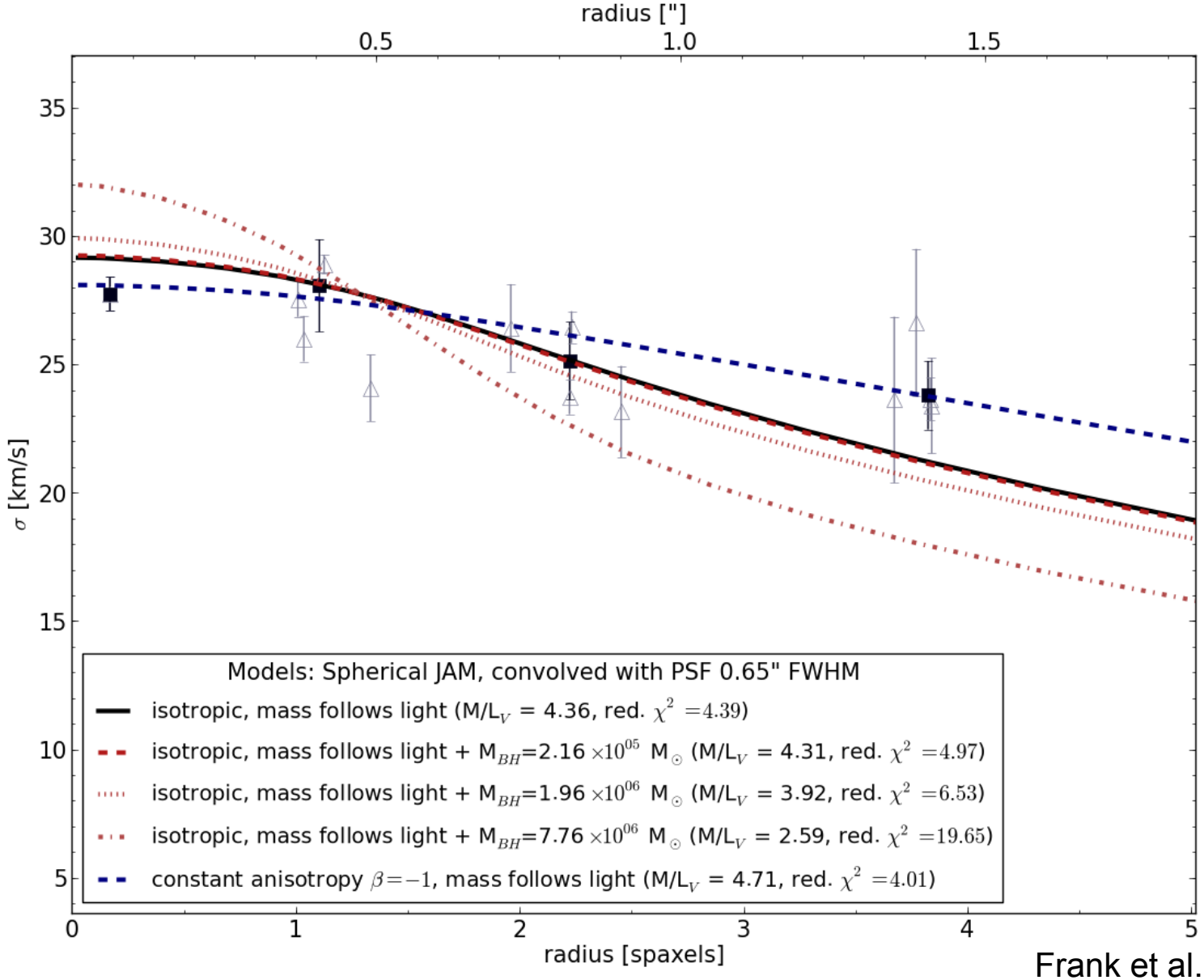
Frank et al. (2010, in prep.)

Velocity dispersion profile vs. models



Frank et al. (2010, in prep.)

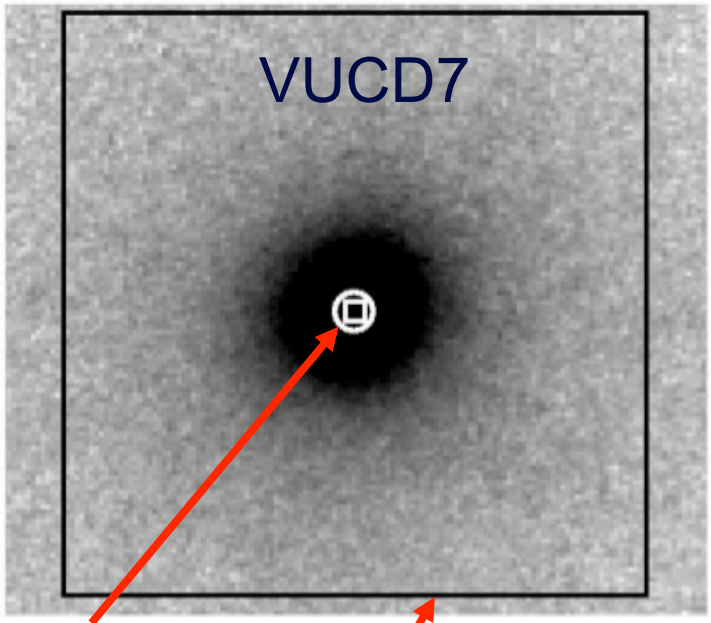
Inner velocity dispersion profile vs. models

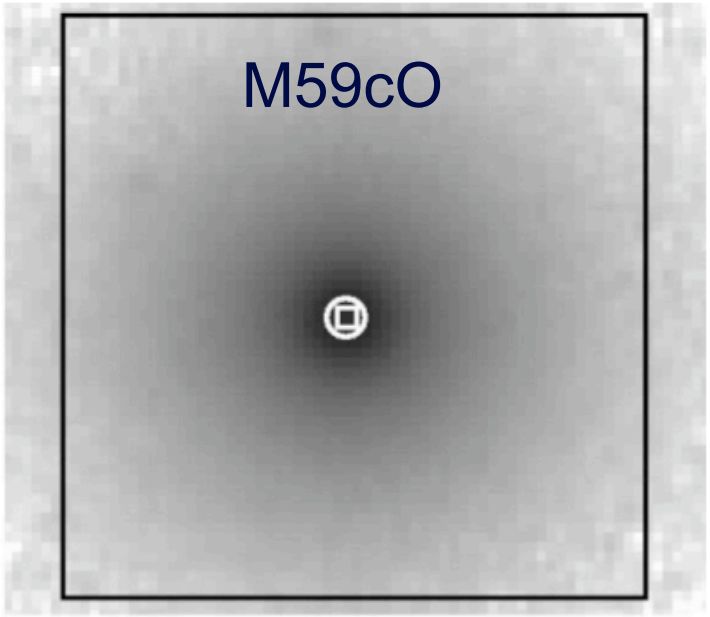


Frank et al. (2010, in prep.)

The next step: AO observations with SINFONI

Two massive UCDs in the Virgo cluster

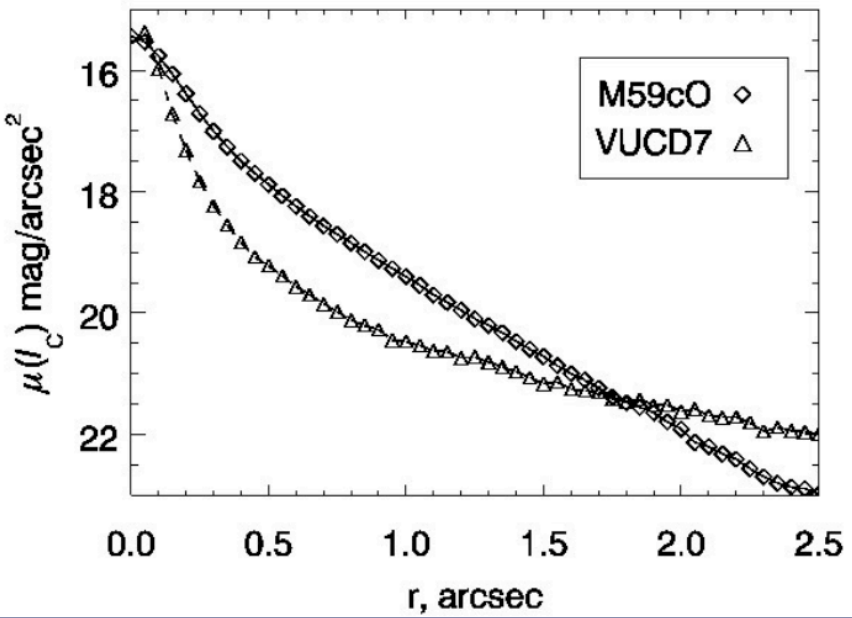




SINFONI pixel and
expected resolution

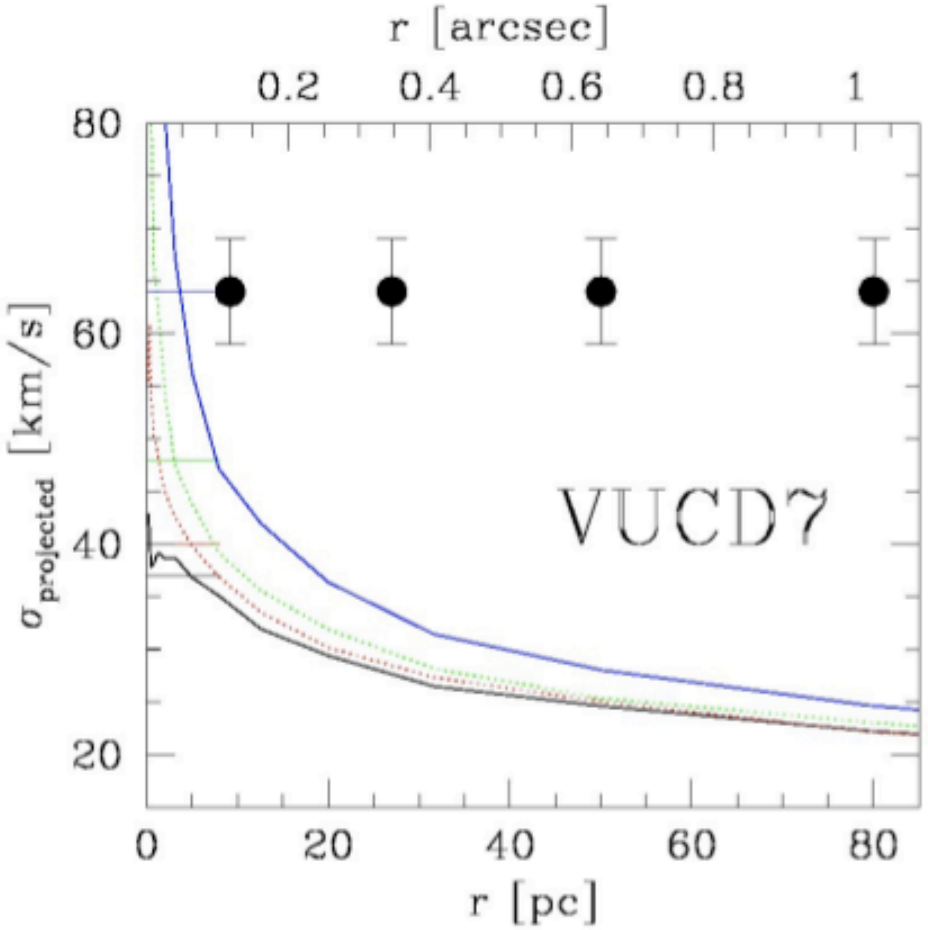
SINFONI 3“x3“ field-of-view

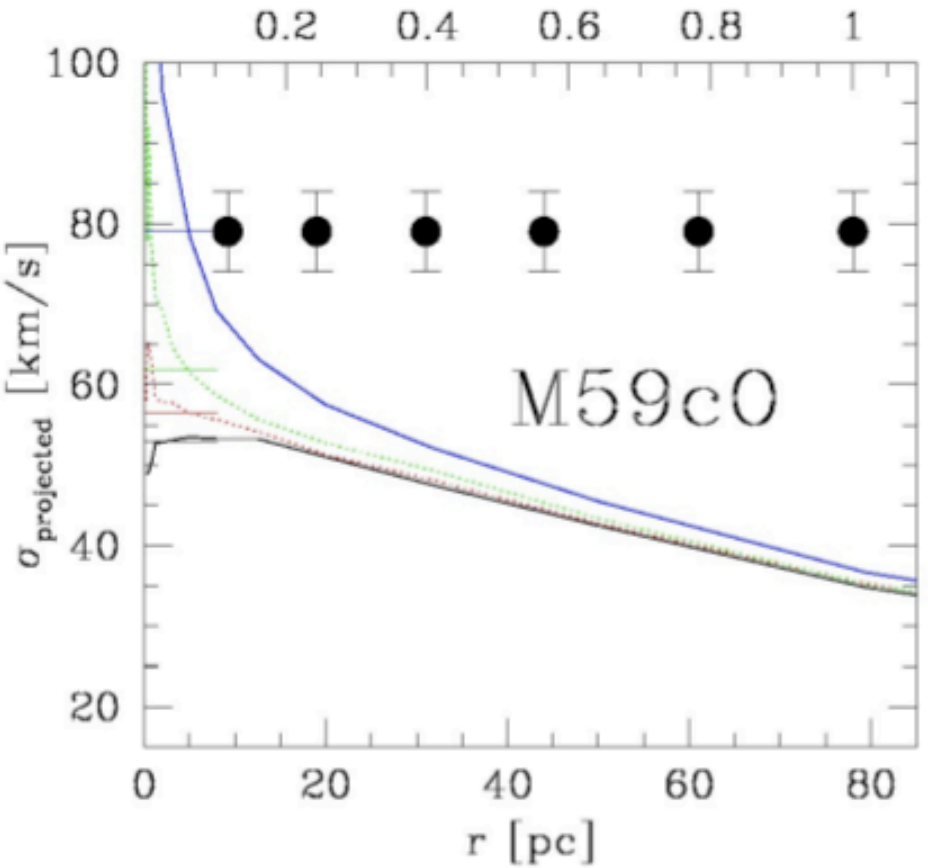
Surface brightness profiles



ESO proposal of P83

Simulated velocity dispersion profiles for different BH masses

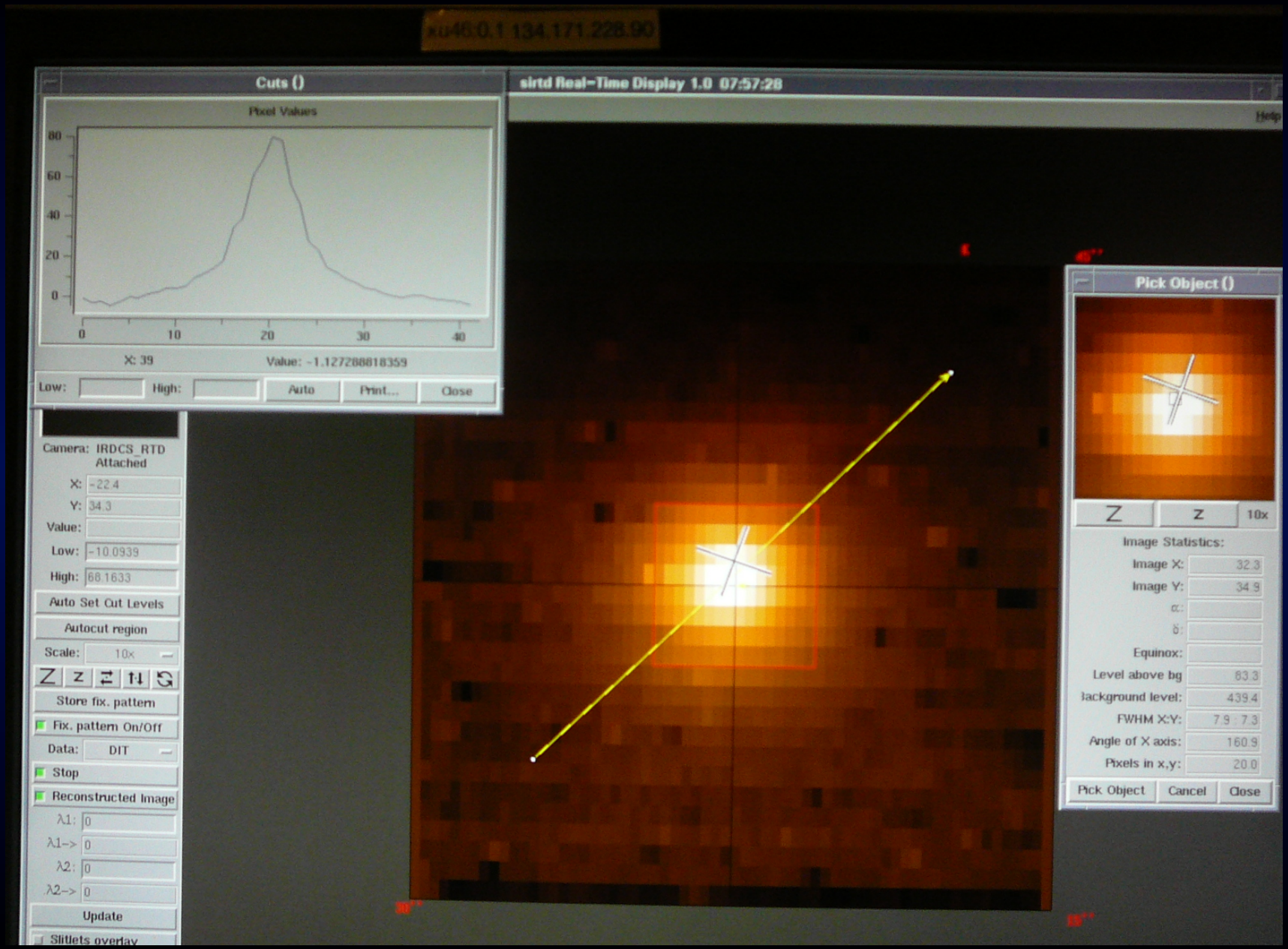




From top to bottom: ratio of BH to total mass: 10%, 3%, 1%, no BH

ESO proposal of P83

First SINFONI observations of M59cO in March 2010

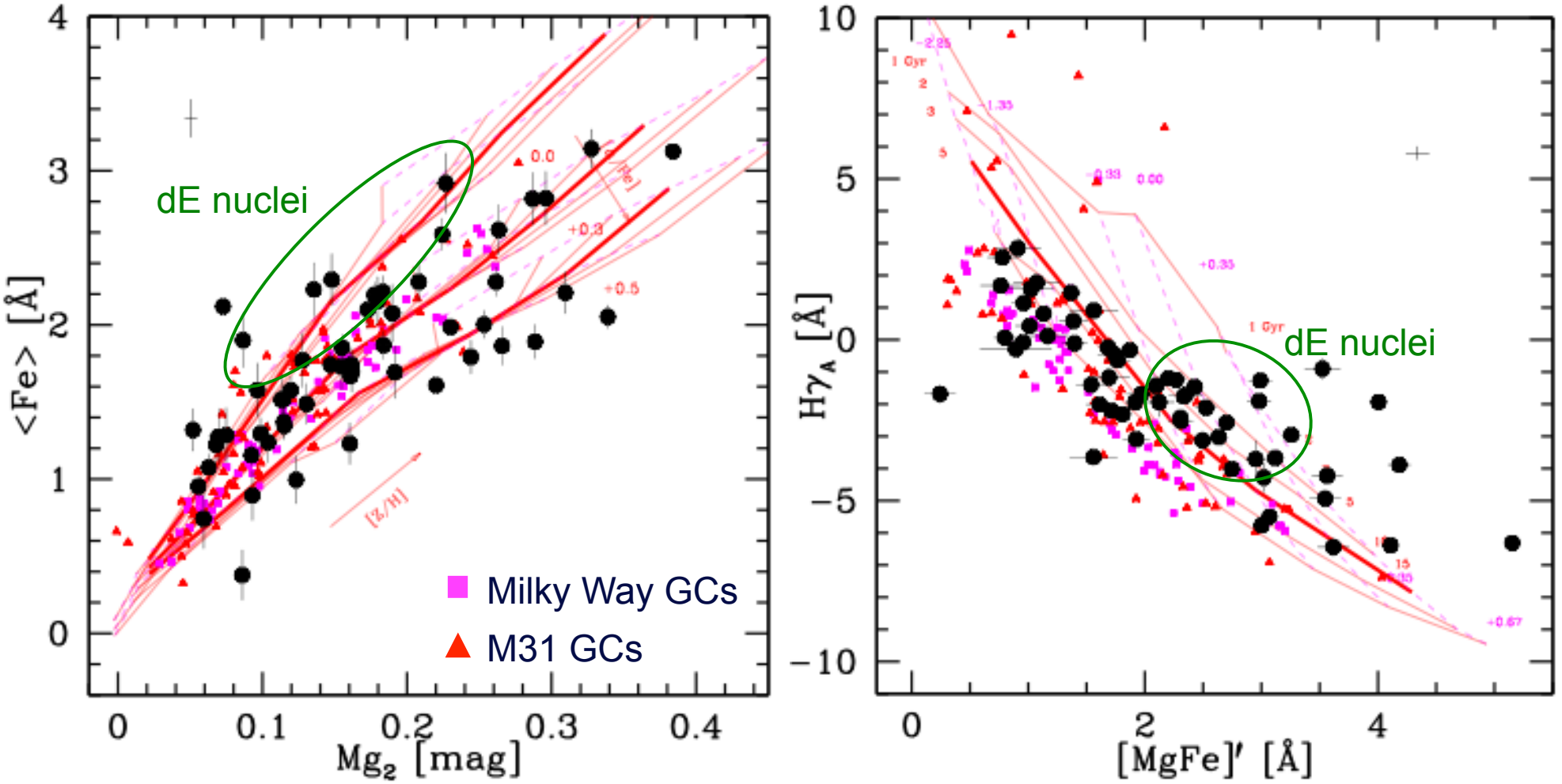


Summary

- UCDs are defined through their mass-size relation and enhanced dynamical mass-to-light ratios – roughly occurring at $>2 \times 10^6 M_\odot$
- UCDs share many properties of nuclear star clusters, e.g. the mass-size relation, an elevated M/L ratio, etc., but also are the "tip of the iceberg" of rich globular cluster systems
  → they are a mixed bag of objects
- UCDs are mostly concentrated around major galaxies but also are found in the intra-cluster space, they do not follow the spatial distribution of nucleated dEs
- Resolving the internal kinematics of UCDs is very challenging, first attempts are underway
- So far there are no indications for black holes in UCDs
- UCDs are a nice scientific case for ELT observations

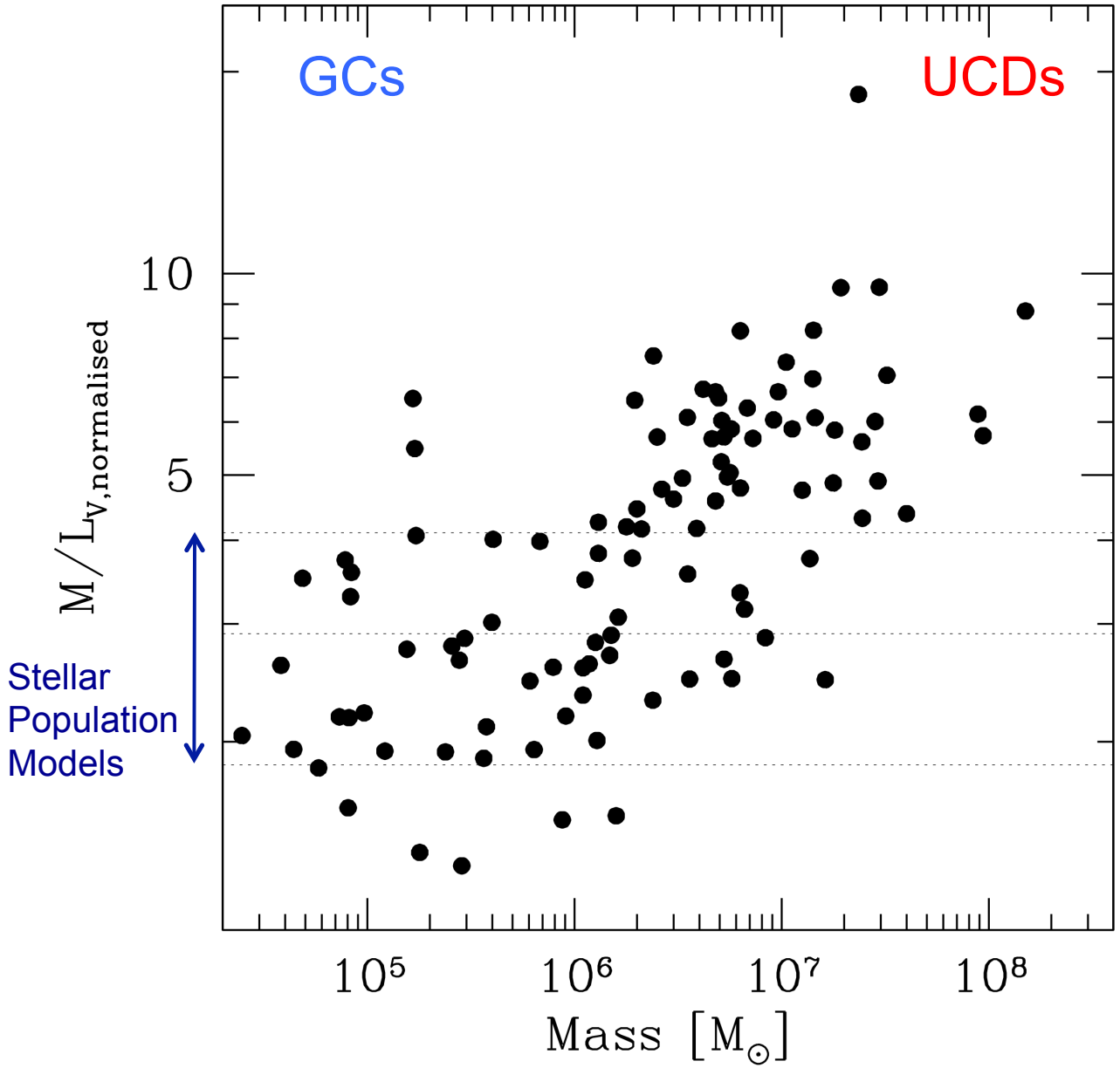
Thank you!

Abundances and ages of GCs/UCDs in the Fornax cluster



High S/N VLT/FORS spectra of ~60 bright GCs/UCDs in Fornax

The M/L_{dyn} values of UCDs cannot be explained by SSP models



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Mieske et al. (2008, A&A 487, 921),
see also: Dabringhausen et al. (2008, MNRAS 386, 864)